A paper prepared for the

Economic Council of Canada

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Ottawa, Ontario
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Un document préparé pour le

Conseil économique du Canada

C.P. 527
Ottawa (Ontario)
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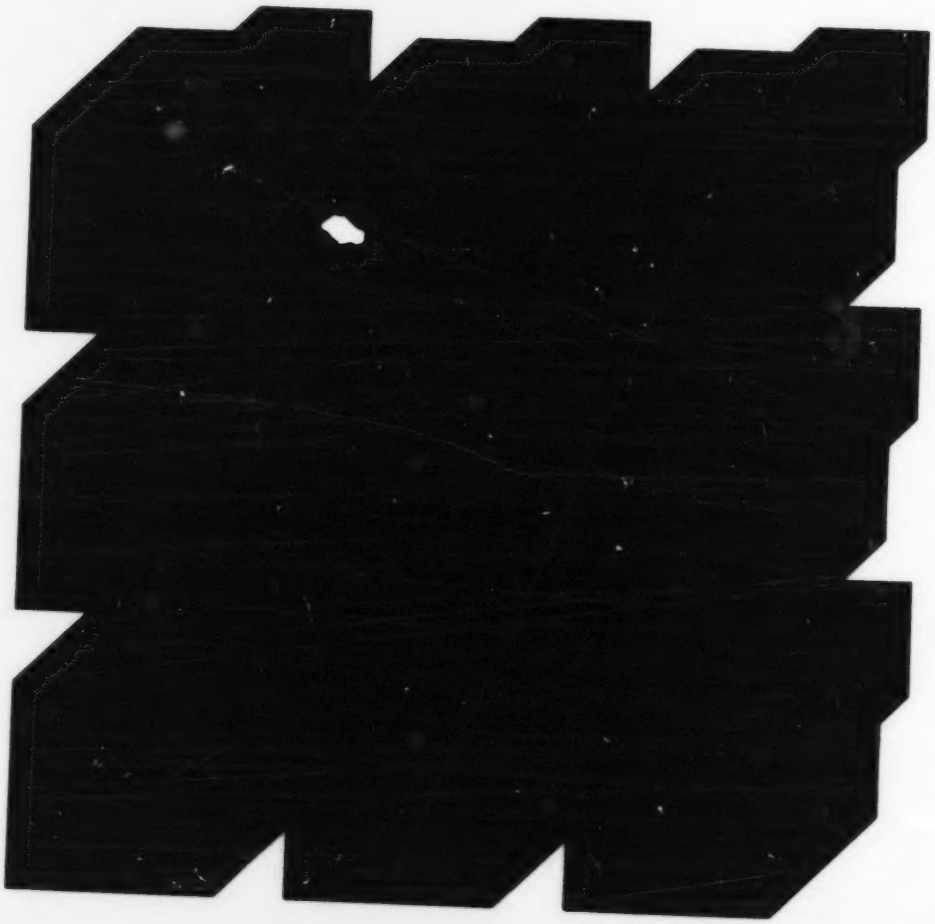

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DISCUSSION PAPER NO. 244

Statistical Problems of Relating Research and Development Data to Productivity Data

by Harry H. Postner

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ISSN-0225-8013

October 1983

ACKNOWLEDGMENT

This paper has benefited from stimulating conversations with Neil Swan and Katherine McMullen at the Economic Council of Canada. Thanks are also due to Humphrey Stead of Statistics Canada (and MOSST) for providing important references and guidance to the research and development statistical literature. The author alone is responsible for the final content of the paper.

RÉSUMÉ

Ce document a comme objet principal d'expliquer les problèmes d'incompatibilité qui peuvent se produire sur le plan statistique lorsqu'il s'agit de relier les données sur la recherche et le développement à des donnés sur la productivité. Ces problèmes sont illustrés le plus clairement possible compte tenu des limites des données canadiennes actuellement disponibles. Un certain nombre de solutions sont proposées pour résoudre ces difficultés d'incompatibilité statistique. Il importe de souligner que la vraie solution dépend essentiellement de la méthode utilisée pour établir une corrélation entre ces deux types de données. L'auteur formule des recommandations précises sur la meilleure combinaison entre les données statistiques cohérentes et la méthode à utiliser pour les études sur les travaux de recherche et de développement et la productivité qui englobent toute l'économie ou le secteur manufacturier. Ces recommandations ont aussi des implications statistiques de portée politique dans le contexte particulier de l'économie canadienne.

ABSTRACT

The main purpose of the paper is to explain the statistical inconsistency problems that can arise when relating research and development (R&D) data to productivity data. The problems are illustrated to the extent possible, given the limitations of presently available Canadian data. A number of suggested resolutions of the statistical incompatibility problem are explored. It is important to note that the appropriate resolution depends essentially on the particular methodology used to relate R&D data to productivity data. The paper makes precise recommendations as to which combination of consistent statistical data and methodology is most appropriate for R&D-productivity studies having economy-wide (or manufacturing-wide) coverage. These recommendations also lead to certain statistical policy implications for the particular Canadian economic context.

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A. INTRODUCTION

During the past few years there has been considerable discussion in Canada concerning the productivity slowdown and the possibilities of restoring reasonable productivity growth. One policy variable that has played a key role in these discussions is research and development (R&D) expenditures. It is often claimed that increased R&D will directly or indirectly stimulate productivity growth by promoting technological advances. A number of Canadian and many American economists have empirically investigated the quantitative relationships between industrial R&D and industrial productivity growth on a disaggregated basis, with results that are often mixed and sometimes difficult to interpret. Most (not all) of these investigations are based on R&D data and productivity data that come from government statistical agencies' surveys. This source of data is particularly essential if the required investigation is to have wide industrial coverage. The history of the investigations shows, generally speaking, that economists were satisfied to use whatever statistical data could be "made available".

Now that more and more Canadian R&D and productivity data are becoming available, it seems natural to re-examine the nature of the two sets of utilized statistics. The main purpose of this paper, therefore, is to show that the two sets of commonly used data are statistically incompatible in the sense that the two sets derive from different statistical reporting units. This

raises the question as to how "serious" the problem really is, and an attempt will be made to provide some illustrations. A definitive account, however, of the related statistical problems would require a paper much longer than the one given here. Even though our account is somewhat brief and incomplete, it is still possible to point in the direction of suggested resolutions of the statistical incompatibility problem and this is done in Sections C and D of the paper. In particular, we make considerable use of the Federal Trade Commission's (FTC, Washington, D.C.) experience with this and related matters. Finally, the paper concludes with a number of statistical policy implications.

B. THE BASIC STATISTICAL PROBLEM

In order to focus on the main issues, the discussion in this paper will be mainly limited to the manufacturing sector. This sector is the subject of almost all R&D-productivity nexus investigations and the sector officially accounts for about 80 per cent of Canadian industrial (business sector) R&D expenditures. Also when referring to R&D, we will mainly have in mind the principal category, namely total (current plus capital) intramural research and development expenditures. The statistical analysis to follow, though, is equally applicable to extramural R&D. The question of whether the (manufacturing) business sector or the government sector is financing the reported R&D will not be distinguished in this paper. All this permits us to focus attention on the precise statistical reporting sources of (manufacturing) productivity and R&D data.

First, it is well-known that Canadian productivity data are essentially based on establishment reporting units. The (manufacturing) establishment is supposed to be the smallest operating unit capable of providing "principal statistics" -- value of output, cost of materials used and data related to labour employed. The rationale for such a unit is to maintain product homogeneity and so permit reasonably unambiguous classification at a fine level of industrial disaggregation. Thus the individual establishment is typically the manufacturing plant or even part of a plant where appropriate accounting data are available.

Sometimes the operations of a closely-related ancillary unit may be combined with the manufacturing plant as a single establishment reporting unit. (Problems connected with the manufacturing firms' headquarters and other distinct ancillary units are discussed in Postner [12] and in the paragraph to follow concerning the statistical reporting of R&D activities). In any event, the statistical notion of an establishment implies that the conceived statistical units must be mutually exclusive and exhaustive with respect to their universe. Note that the idea of basing productivity statistics on establishment reporting units is essentially invariant as to whether productivity is measured by simple labour productivity, multi-factor productivity, or by a generalized input-output productivity calculus.

Second, it is rather less well-known[1] that Canadian R&D expenditure data are <u>not</u> based on establishment reporting units. To quote directly from Statistics Canada [18, p. 26]:

> "In these surveys, the reporting unit is generally the company (which is a legal entity such as a partnership or corporation). This unit has been used because R&D is generally a centralized activity. Sometimes replies are received for an entire company group."

It should be clear that where a "company" consists of only one establishment or where all the establishments are officially

assigned to the same industrial classification (as the parent company), then there is no real conflict between the two types of reporting units. A conflict, however, can arise where the company or enterprise (group of closely related companies) reporting R&D activities consists of establishments operating in various industries, i.e., multi-industry companies. In this case the company and all its R&D expenditures is officially classified to the single industry where the company has more operations as compared to any other single industry. But, at the same time, production and productivity data are reported over the full range of diverse industrial classifications. Indeed, small shifts in intracompany production distribution can lead to catastrophic changes in company and, therefore, R&D industrial classification. Hence there is a statistical incompatibility problem. Again it should be evident that even this might not be a serious problem if the reporting companies' (manufacturing) operations are mainly concentrated in a single industry. The problem, though, is most apparent for those large multi-industry conglomerates with diverse industrial operations, no one of which dominates all others. Two further points should be stressed: (1) the company-establishment statistical problem is potentially most serious where an empirical investigation requires a fine industrial classification, and (2) a good deal depends on the exact nature of the "company" reporting unit and the distribution of (in our case) business sector R&D among the individual reporting companies.

Before continuing it might be asked why R&D expenditures cannot also be reported on an establishment basis just as principal industrial statistics. Such reporting is, of course, natural for a single establishment company. In the case, however, of a multi-establishment company, R&D activities tend to be centralized in either headquarters or special R&D ancillary units serving all other establishments of the same company. The individual (manufacturing) plants' accounting records would typically contain little or no information relevant to R&D, although company headquarters may or may not have a R&D expenditure allocation system (discussed later in this paper).[2] Indeed, the statistical situation with respect to R&D is similar to that of other financial variables such as interest payments, taxation credits, and balance sheet information -- all of which are company reported.[3] Note that these comments apply mutatis mutandis whether R&D expenditures are of the intramural or extramural type.

Suppose, then, the investigator wishes to relate productivity data to R&D data (possibly using econometric methods and other data variables). We will assume that such an investigation should proceed at a fine level of industrial disaggregation, say the 3-digit level. This assumption would tend to avoid most problems of compositional (aggregation) fallacy. So long as most R&D data come from single establishment or single industry companies, then the statistical incompatibility problem is certainly not serious. Even if this condition is not

satisfied, one may conceive of a somewhat "weaker" condition which would still preserve reasonable compatibility between the two sets of statistical data. This weaker condition implies that R&D expenditures by company are distributed more or less proportionally to value of production (or labour employed) by company and that the largest R&D performing companies have operations mainly in one dominant 3-digit industry. A further weaker condition might even appeal to the "law of large numbers" whereby statistical incompatabilities could tend to cancel out when there are a large number of R&D performing companies no one of which or few of which dominates all others in terms of relative importance. It should also be noted that the severity of the statistical problem would depend on the exact nature of the methodology used to relate productivity and R&D and on the particular observations turning up during the investigated time period or industrial cross-section. Clearly the statements in this paragraph really call for a more formal (mathematical) analysis which is not attempted in this paper. It is possible, however, to now provide some empirical background.

Table 1 shows the relative concentration of Canadian industry R&D expenditures by top company performers. The table covers all business sector total intramural R&D for selected recent years. The table reveals that Canadian R&D is largely concentrated in a small number of reporting companies. For example, in the most recent year 1982, the top 10 Canadian performers account for almost 50 per cent of total industrial R&D

Table 1

Industry R&D Expenditures by Top Performers
(as a percentage of total industry R&D)

Year	Top 10	Top 25	Top 50	Top 100
1973	35.2	50.5	64.0	76.7
1975	40.0	50.8	64.1	75.7
1977	36.1	52.5	65.7	78.1
1979	37.8	53.6	66.8	79.7
1981	38.7	56.5	69.9	81.8
1982	49.7	66.0	78.9	91.1

Source: MOSST, Science Notes, Fall 1982, p. 7.

and the trend towards greater concentration is clearly evident. This means that any R&D-productivity empirical analysis will be largely influenced by the particular R&D expenditures reported by a small number of Canadian companies and by their official industrial classification (according to the official "rule" mentioned earlier). We could now ask how Canadian company R&D concentration compares with the corresponding concentration of Canadian company value of production. Though it is difficult to make exact corresponding comparisons, it is possible to show some rough comparisons using data available in Statistics Canada [19]. For example, we find that the leading 500 Canadian enterprises, consisting of some 3,500 individual corporations, account for about 55 per cent of total production sales by all Canadian nonfinancial corporations in the year 1978.4 The same large number of enterprises and corporations account for about 65 per cent of total Canadian assets held by all Canadian (nonfinancial) companies. By any measure, then, Canadian R&D is a much more concentrated affair compared with Canadian production indicators. This fact should at least alert us to the possibility that the statistical incompatibility problem might be serious. The Canadian production data in a R&D-productivity analysis, would reflect, in terms of weight, a much larger number of reporting companies compared to the Canadian R&D source data.

We must still, nevertheless, show that the top R&D performing companies are industrially diversified in order for there to be a clear conflict between the establishment and

company statistical reporting bases. This would require knowing: (1) the names of the top reporting companies[5], (2) their official Statistics Canada industrial classification (usually a single 3-digit industry), and (3) their multi-industry production activities and relative importance of industrial diversification (again, preferably by 3-digit industries). This is a "tall order" since the required data cannot come directly from government sources due to confidentiality restrictions. In order to at least approach the problem we first display Table 2 based on U.S. data and private source information (the U.S. government confidentiality limitations are similar to those of Canada). The table shows the 15 largest U.S. R&D performing companies in the year 1979 as reported in the companies' Annual Reports or similar sources. It is interesting to note that the company concentration of U.S. R&D expenditures is of an order-of-magnitude similar to that of Canada. For example, the top 20 U.S. R&D performers account for about 40 per cent of total U.S. business sector R&D in the years 1979 and 1980 (further details can be found in National Science Foundation [6]). The degree of concentration becomes higher, and similar to that of Canada, when U.S. Federal R&D funding is added to that of the business sector. It might also be noted that Japan's R&D effort is significantly less company concentrated compared to both Canada and U.S.; the U.K. R&D concentration is even higher than that of Canada (see OECD [8] for more discussion).

Table 2

United States: R&D Expenditures of 15 Largest Companies, 1979

Rank	Firm	Million Dollars	Number of Different 3-Digit Activities
1	General Motors	1,949	18
2	Ford Motors	1,719	-
3	IBM	1,360	-
4	AT&T*	980	21
5	General Electric	640	32
6	United Technologies	545	15
7	Boeing	525	-
8	Eastman Kodak	459	-
9	IT&T	436	31
10	Du Pont	415	-
11	Exxon	381	-
12	Xerox	376	-
13	Chrysler	358	-
14	Dow Chemical	269	-
15	Minnesta Mining & Mfg.	238	15

Source: OECD Science and Technology Indicators, Sept. 9, 1982 and Scherer [14].

Note: * Includes Western Electric.
- Indicates no comparable information available.

Returning to Table 2, we have been able to learn the number of different 3-digit codes under which 6 of the 15 listed companies have significant production activities. For example, our old friend General Motors operates in 18 different 3-digit activities; General Electric appears in no less than 32 different 3-digit codes. The information in the second column of Table 2 comes from FTC sources as in Scherer [14]. Unfortunately, for the remaining 9 companies listed in Table 2, we have no information, but this certainly does not imply that these well-known large corporations are not industrially diversified! On the limited basis of Table 2 it seems fair to conclude that R&D activities tend to be concentrated in large multi-industry corporations so that the company-establishment statistical problem is evidently serious, at least based on U.S. data.

Table 3 presents the names of the 25 largest Canadian company R&D performers as reported in Financial Post (FP) for the year 1982. The FP survey is apparently consistent with companies' Annual Reports when these Reports contain R&D expenditures information (which is not always the case). On the other hand, the FP survey is not necessarily consistent with Statistics Canada R&D data since the particular methodology used is not identical and the FP survey is designed to be voluntary meaning that some large R&D performers may be entirely missing from the list of Table 3. Nevertheless, Table 3 is as close as we could come to identifying the largest Canadian company R&D performers.[6] The table also provides the single 3-digit industrial code to which

Table 3

Canada: R&D Expenditures of 25 Largest Companies,** 1982

Rank*	Firm	Million Dollars	Single 3-Digit Code
1	Bell Canada	336	544, 335
2	Pratt & Whitney	118	321
3	Hydro-Québec	67	572
4	Ontario Hydro	65	572
5	Alcan	49	295
6	Mitel	31	335
7	Imperial Oil	51	365
8	IBM Canada	35	318
9	General Motors of Canada	30	323
10	CIL	26	379
11	Shell Canada	20	365
12	B.C. Telephone	19	544
13	CAE Industries	19	335
14	Canadian General Electric	18	336
15	NCR Canada	17	318
16	Inco	20	296
17	Noranda	15	297
18	Nova	10	515
19	Nabu	11	335
20	Syncrude	18	064
21	Canadair	14	321
22	Control Data Canada	12	339
23	Du Pont Canada	12	378
24	MacMillan Bloedel	14	271
25	Dow Chemical of Canada	11	378

Source: Financial Post, March 12, 1983 and unpubished information provided by MOSST and Statistics Canada.

Note: * Ranks are for 1983 where R&D are projected.
** Excludes Atomic Energy of Canada and Canada Development Corporation Group.

Statistics Canada categorizes these particular companies. (For one of the companies shown there is more than one 3-digit code since the Statistics Canada reporting unit is not always identical to that of FP). Thus, for example, Pratt & Whitney is assigned to SIC number 321 (Aircraft & Parts); Imperial Oil is categorized to SIC no. 365 (Petroleum Refineries); Bell Canada is assigned two different SIC codes, namely no. 544 (Telephone Systems) and no. 335 (Communications Equipment).7 The reader can trace the identity of all SIC numbers as given in Statistics Canada [20] and [21]. Thus, we now see directly, that (almost) all the large R&D performers are officially given one (usually) 3-digit industrial classification in so far as their R&D expenditures are concerned. The production activities of each of these same companies may, on the other hand, appear in a number of different 3-digit activities.

It would, therefore, be most informative if we could add to Table 3 the precise number of 3-digit industrial activities under which each of the listed Canadian companies has production operations. This was, in fact, done in Table 2 for some top U.S. R&D performers. Unfortunately, no such reliable Canadian information is available to this writer at this time. Instead, an attempt was made to examine Annual Reports for any relevant information, i.e., voluntary segmented financial reporting of the various companies (this is discussed again in Section D). It is, again, unfortunately exceedingly difficult to relate this information, even when available, to precise SIC industrial codes.

All we could really do is give a number of impressions, limited to those companies assigned a manufacturing SIC code (recall that most productivity-R&D growth investigations are limited to the manufacturing sector). For example, we know that part of Bell Canada is assigned to SIC no. 335 via Northern Telecom. Examination of Northern Telcom Annual Reports appears to reveal operations in SIC nos. 336 (Electric Industrial Equipment) and 339 (Other Electric Products). Imperial Oil has significant operations in SIC nos. 064 (Crude Petroleum), 369 (Petroleum and Coal Products), 379 (Other Chemical Products), 162 (Rubber Products), as well as 365 (Petroleum Refineries).8 The situation with respect to Shell Canada is probably somewhat similar. Canadian General Electric has production under SIC nos. 331 (Small Electrical Appliances), 332 (Major Appliances), 338 (Electric Wire and Cable), as well as 336 (Electrical Industrial Equipment). Further evidence will be offered in the next Section C that the major Canadian R&D performers are typically multi-industry corporations with diverse operations even out of manufacturing. One more example: Statistics Canada assigns all CIL R&D to SIC 379 (Other Chemicals) even though CIL is active in textiles, plastics, petroleum products, and a wide range of chemical products (aside from SIC 379).

Before concluding this section it might be noted that some very large Canadian corporations are conspicuously absent from Table 3. For example, there is no sign of the Canadian Pacific (CP) Ltd. group (the number <u>one</u> Canadian industrial

corporation in terms of sales).9 A check of the latest 1982 CP Annual Report reveals no information concerning R&D expenditures. It would appear that Financial Post was unable to learn anything about CP R&D though, of course, all such R&D must have been (confidentially) reported to Statistics Canada. The situation with respect to Ford of Canada, Texaco Canada, and Chrysler Canada would appear to be similar.

Notes - B

1 This writer has been unable to find references to a possible conflict between productivity and R&D data in the Canadian economic literature (e.g., McFetridge [5] and Palda and Pazderka [11]) though, as we shall see, Statistics Canada has made no secret of the problem.

2 Even if such an allocation system does exist, the required information must come from company headquarters and not from individual establishments' (manufacturing) census data.

3 The statistical reporting of R&D is also similar to that of purchased producer services; see Postner [12].

4 This particular measure and other similar measures have remained fairly constant in recent years.

5 Note that the statistical definition of "company" is quite vague and flexible: companies may report grouped as "enterprises" or even distinctly as individual company "divisions". Some examples are given later.

6 Two large R&D performers listed in FP are not present in Table 3. Atomic Energy of Canada is not part of the Canadian business sector and Canada Development Corporation actually reports R&D to Statistics Canada via eight different companies each with its own SIC code (e.g., De Haviland).

7 Northern Telecom now reports R&D to Statistics Canada distinct from the rest of the Bell Canada group.

8 Not to mention Imperial Oil's activities in transportation, storage, wholesale and retail trade.

9 CP ranks number 3 in terms of assets. The CP Annual Report does provide good information concerning multi-industry production operations.

C. RESOLUTION OF PROBLEM BY "PRODUCT FIELD" DATA

This, and the following section, will discuss two possible resolutions of the company-establishment statistical problem outlined in the previous section. First, though, one rather natural solution may have already occurred to the reader: why not merely measure production and employment data on a company statistical basis and so avoid the potential incompatibility problem between productivity and R&D data. To support this argument, we know that productivity statistics already collected on an establishment basis can be appropriately reassigned, using micro identification codes, and thus transformed into productivity data on a company basis. In fact Statistics Canada has already furnished various sets of data (not directly productivity data), normally collected on an establishment reporting basis, into a company or enterprise statistical system (see, e.g., Statistics Canada [22]).[1] In this way, it would be possible to perform R&D-productivity nexus investigations on a statistically consistent basis. This "solution" to our problem is certainly feasible, but <u>not</u> recommended. Considerable evidence was presented in the previous section showing that the top R&D performing companies typically operate in diverse multi-industry activities. To simply aggregate these establishments' activities into company data would defeat the homogeneity feature of establishment-based productivity statistics. A time series analysis of such transformed (company) data would present problems of compositional change difficult to identify unless the establishment decomposition is somehow

preserved. It might be noted, though, that some investigators have studied R&D-productivity relationships on a company statistical basis using private (non-government) sources of information. These studies, however, do not have economy-wide (or manufacturing sector-wide) coverage which is an essential aspect if both the direct and indirect relationships of R&D-productivity are to be exposed.[2] We, therefore, in the remainder of this paper restrict our attention to "making" R&D data compatible with establishment-based productivity data, rather than the other way around.

It has been suggested by the authoritative OECD [9] publication on R&D measurement, that an allocation of R&D expenditures by "product field" might provide a better basis for comparison with production statistics (than company classified data alone). The general idea is to still survey R&D expenditures on the company-reporting statistical basis, but provide tabulations on a product field basis that is expected to be more homogeneous and comparable. In this case each surveyed company is requested to allocate all (intramural) R&D according to a designated list of R&D product fields. (The notion of "product field" encompasses R&D on processes as well as new and improved products). We should, therefore, expect the top R&D performers that are large multi-industry corporations, to allocate their R&D to a number of different R&D product fields. The designed list of product fields can be made to approximate establishment-based industry classifications (e.g., the 2½- or 3-digit code).

Clearly, a good deal would depend on the precise survey questionnaire with respect to R&D product field. There are, in fact, two major methods of designing the relevant question.

First, product field can be defined on the basis of a "use" criterion. This criterion can be best described by quoting directly from an old Statistics Canada [23, p. 54] R&D survey where the product field ("use") criterion was actually applied:

> "Consider R&D on behalf of the end product. For example, the cost of the R&D necessary to create a chemical for use in making synthetic textiles should be entered beside the (product) field Synthetic Textiles. An electronic component developed specifically for an airplane should be considered part of the Aircraft field, whereas a general purpose component should be considered in the Electronics Components and Accessories (product) field."

Statistics Canada [23, Table 11] provides a matrix of R&D expenditures for the year 1965 cross-classified by company-reporting industry and company-reporting product fields (the data are all aggregated at something approaching the 2-digit industrial level). It is reasonably clear from this Table that some Canadian industries perform R&D in a variety of different product fields

(by "use") and these fields are sometimes far removed from the official industry of origin to which companies are classified.[3] This latter statement is particularly relevant to Paper and Allied Industries, Aircraft and Parts, Electrical Products, and Other Chemical Products. Statistics Canada decided to discontinue publication of the matrix-type R&D data in the late 1960's, since the full matrix tended to reveal confidential R&D expenditures (i.e., R&D activities for single Canadian companies). If the confidential cells of the matrix had been suppressed, then most (or many) "off-diagonal" cells would be simply marked "confidential" and the resulting published matrix would lose much of its valuable information. It appears, however, to the present writer that the time has arrived to re-examine this decision. There are now (1983) many more Canadian R&D performers as compared to the year 1965, so that confidentiality restrictions should be less limiting. Furthermore, it may not be necessary to publish the complete R&D matrix display; if both row totals and column totals were publicly available this would add significantly to our knowledge of Canadian R&D. At this moment we only have (industry of origin) row totals -- posing the company-establishment statistical problem. Column totals showing R&D by individual product fields would go some way towards resolving this problem.

There are, nevertheless, reasons for suspecting the quality of R&D data by product field ("use" criterion). The allocation of company R&D by product use field is evidently a

subjective matter, so that intercompany comparisons become difficult. A good deal depends on the particular market situation[4] and, perhaps, company-ownership and-control of the R&D performers. Companies engaged in extensive R&D would need rather detailed technical records of R&D projects together with specific engineering guidelines in order to effect the allocation criterion. Most important, for our purposes, it is not clear whether R&D classified by product use field is the appropriate R&D indicator to match up with establishment-based productivity data in the kind of investigations which are our main concern. Some thought concerning this subject leads to questions of statistical ambiguity and difficulties of interpretation (see next section). Before leaving this matter, we now discuss the second major method of designating R&D product fields.

The second method is applied according to a "nature of product" criterion, i.e., R&D expenditures are requested according to distribution (allocation) of type of product or process being developed. This method is utilized by the National Science Foundation (NSF), and to quote [7]:

> "Costs should be entered in the field or product group in which the R&D project was actually carried on regardless of the classification of the field of manufacturing in which the results are to be used. For example, research on an electrical component

for a farm machine should be reported as research on electrical machinery. Also, research on refractory bricks to be used by the steel industry should be reported as research on stone, clay, glass, and concrete products rather than primary ferrous metals, whether performed in the steel industry or the stone, clay, glass and concrete industry. R&D work on an automotive head lamp would be classified in Other Electrical Equipment and Supplies, regardless of whether performed by an automotive or electrical company."

This method has the advantage of being somewhat less subjective compared to the first method (embodying a "use" criterion). There are problems, though, in classifying R&D on processes according to the second method and specific guidelines are again required. One disadvantage, mentioned in OECD [9], is that R&D on products assembled from a wide range of components, such as aircraft, may be underestimated by application of the "nature of product" criterion. Most important, however, is the particular experience gained by NSF with this method. A recent internal audit by the U.S. Bureau of the Census, which carries out the R&D survey for NSF, shows that the majority of R&D respondents interprets the question concerning distribution of R&D by "nature of product" <u>as if</u> the question related to product field according to "use" criterion.5 Thus the idea of resolving the company-establishment

problem via "product field" R&D reporting can lead to statistical ambiguities and questions of interpretation. Indeed, the methodology for relating R&D and productivity must depend on the exact nature of R&D data being generated.

Notes - C

1 Clearly it is a lot easier to "add up" establishments' data into parent-company data compared to "dividing up" company data into component establishments' data.

2 See, e.g., the importance of the indirect relationships in Postner [13].

3 Recall the official rule by which companies are industrially classified to the single industry where operations are greater than any other single industry.

4 It might be noted that in 1971 Statistics Canada [24, Table 16] introduced a cruder version of the R&D product field allocation whereby company-based (intramural) R&D expenditures were grouped according to "markets" for which new products and processes were developed. The "markets" could be industrial, government, or consumer, each with designated sub-markets. This version was discontinued in the early 1970's.

5 This is made clear in Griliches and Lichtenberg [4].

D. RESOLUTION OF PROBLEM BY "LINE OF BUSINESS REPORTING" DATA

To recapitulate, the statistical problem of this paper originates in the practice of R&D expenditures being statistically reported on a company-unit basis. Thus even if a company has industrial operations in a particular 3-digit industry which may only represent, say, 20 per cent of total industrial operations, all the company's R&D would be classified to that particular 3-digit industry if no other single industrial operation accounted for, say, more than 20 per cent of total operations. This kind of situation is most common where business sector R&D is dominated by a few large multi-industry corporations or enterprises, particularly when R&D reports are not forthcoming from individual corporate subsidiaries (but are referred up the corporate hierarchy of the parent organization). At the same time production and productivity statistics do in fact reflect the complete rangel of each company's industrial operations due to the nature (and purpose) of establishment-unit reporting. It would seem natural to attack this inconsistency problem by re-examining the basis of R&D company reporting practices. Most of this section, therefore, will focus on the experience gained by the Federal Trade Commission (FTC) in Washington D.C. with regard to their line of business (LOB) reporting program. The program actually covers a wide range of traditional company-reported (financial) data, but we will concentrate attention on the LOB program relevant to R&D expenditures. The Conclusion Section E will attempt to put the program in a wider Canadian perspective.

The general idea of LOB reporting is to obtain financial and related data from large multi-industry companies with respect to their individual industrial operations. These data are normally and traditionally surveyed only at the consolidated- or combined-industry company level. It is now increasingly recognized that large companies must keep detailed financial accounting records of their internal operations for purposes such as: management control, allocation of investment funds, and formulation of pricing policies. The particular form of these accounting records do differ from company to company, but there are also significant similarities. Indeed these similarities have probably become more apparent in recent years as witnessed by the rise of the field: management accounting.2 The general rationale of LOB reporting, then, is to tap these internal sources of information, sometimes referred to as "management information systems". To be clear, LOB reporting does not necessarily require any more detailed or disaggregated data than is not already available, in one form or another, to company management. In fact most "complaints" about LOB reporting center around the need for company accountants to re-combine or aggregate existing company internal data or information into a format required by the particular LOB program. Now, how is all this related to the statistical problem of this paper?

First, we must explain what is meant by a "line of business". For our purposes we could regard a line of business as merely one of the 3-digit industrial activities in which a company

has operations. Thus LOB reporting requires a set of financial and related data for each and every 3-digit industry in which the company has significant3 operations. (It should be noted that this description of LOB reporting is a considerable simplification of the procedure actually used by FTC [3]). We already mentioned earlier in this paper that R&D expenditure data can be regarded as similar to financial-type data in the sense that such data are not typically available at the establishment-reporting level, but must be obtained from company-wide sources. The internal accounting records of the corporation are normally found at company- and/or division-headquarters which is also where the company's management accounting expertise is located. Thus LOB reporting with respect to R&D calls upon the company's accounting expertise to use their available information to allocate all the company's R&D expenditures to the various industrial operations in which the company has significant activities. Clearly this can only be done where: (1) a company-wide view is available, and (2) the government authority (e.g., FTC) requiring such reporting should be able to furnish some suggested allocation guidelines, but <u>flexibility</u> is the order-of-the-day! Any such reporting requirements must respect the individuality and special internal knowledge of the various companies performing R&D. There is no way in which a government official sitting in Ottawa can tell a company accountant with many years' company experience and (computer) access to management information systems,4 how to allocate his (or her) company's R&D expenditures. Nevertheless, FTC does provide some guidelines that run somewhat as follows.

It is useful to distinguish between R&D on industrial processes and R&D on (new) products. For processes, the allocation should be straightforward: a company performing industrial process R&D is presumably trying to improve the production technology of one of its own active operations, so this particular (3-digit) operation should normally receive the allocation. This "rule" could hold across the range of the various industrial process R&D projects. It is possible, of course, that an entirely new industrial process is being developed, entirely "unrelated" to current operations. In this case, companies are suggested to choose that (own) industrial activity which seems closest to the R&D process project. This problem is evidently not serious since the FTC and the scope of this paper is mainly restricted to (manufacturing) business sector R&D, where commercial considerations are immediately apparent.[5] With regard to R&D expenditures on (new) products, the situation is a little more complex. Companies are asked to try to allocate such R&D to the particular current industrial operations where the new product would normally be manufactured (assuming commercial viability). Note that new product R&D is typically not used, after development, by the performing company's own industrial operations, but may be sold externally to another company (thus the critical difference as compared to industrial process R&D). The criterion, then, requires some judgement and internal knowledge of the company's R&D investment program including the particular company's accounting system with respect to R&D projects (a good introduction to these issues can be found in

Batty [1]). One further complication arises when the company's new product R&D is externally-financed, i.e., contracted R&D (this is still part of intramural R&D). In this case it may be possible to allocate the contracted (new product) R&D expenditures to one of the company's industrial lines of activity where, again, the new product might be put into production after commercial development. There could, nevertheless, be examples where R&D allocation to a company's own industrial operation might prove to be entirely arbitrary. Such examples would tend to be rare particularly for companies with sophisticated R&D accounting and control systems (see, again, Batty [1]).6 Finally, it might now be evident why this paper focuses mainly on intramural R&D. For extramural R&D, i.e., R&D not performed within the company but paid for by the company (also called contracted-out R&D), it would be very difficult to allocate such R&D to the company's own industrial lines. Fortunately, or should we see "officially", this is not an important problem for the Canadian business sector R&D, since extramural R&D is very small compared to intramural R&D.7

Thus we see that by following the FTC guidelines it is possible to "create" R&D expenditure data that approximate establishment-type statistical reporting and so match up with basic productivity data observations. Indeed, the FTC has apparently had no serious administrative problems with this particular aspect of their program, though some difficulties were experienced with other phases (and changes were necessary).8 This

does not necessarily mean that a similar R&D-reporting program can work in Canada. A number of relevant considerations would include: (1) the FTC program contains much more than just R&D allocation, (2) there are probably additional problems for foreign-owned Canadian companies in the sense that complete management accounting records may not be available at Canadian (regional) headquarters, and (3) the valuation of Canadian business sector R&D can be manipulated by intracompany transfer price arrangements. It might also be stated that the FTC program represents a more rigorous set of reporting requirements as compared to the U.S. Securities and Exchange Commission (SEC) accounting disclosure requirements to which companies were already exposed. Thus the FTC program had some precedents to build upon. For Canada, these precedents are somewhat weaker (further discussion in next section).

It is revealing to compare R&D allocation according to FTC-type guidelines with that described in Section C, namely R&D by product-use field. The latter method is partly motivated by the idea that it is the ultimate industrial user of R&D, and associated technological advance, that actually benefits from such R&D, say, benefiting in terms of industrial productivity growth.9 We have no quarrel with this argument. It is, however, not evident from basic R&D data alone, which particular industries are the ultimate "users" of the R&D. Indeed, it requires a major inference effort and substantive judgment as to how this "user" allocation should be enforced.10 The opinion of the present

writer is that the "user" emphasis given to the R&D statistical problem is misguided. Those investigators who stress the importance of the "user" allocation evidently fear that there may be no other method of positioning productivity growth with R&D used. So arbitrary techniques are introduced to enforce such positioning while, in reality, the positioning criterion is a major unknown of the essential problem! We prefer, therefore, to work with an FTC-type R&D allocation in which the R&D data approximates establishment reporting and so is statistically compatible with productivity data. But, this allocation alone cannot position R&D data with productivity observations on the basis of R&D by industrial use. In fact the unknown (correct) positioning can be estimated from the complete collection of statistically consistent data if the methodology deployed to relate productivity to R&D is sufficiently powerful. One such methodology is the full force of input-output analysis, accounting not only for "first-order" industrial uses of R&D, but all "higher-order" uses as well. The methodology is illustrated in Postner and Wesa [13, Ch. 4] though the basic R&D data available to that study was not statistically consistent with the industrial productivity observations. It would be most revealing to rework the input-output calculations of that study after more statistically compatible data become available.11

One final point is now mentioned. If an FTC-type R&D allocation is introduced, it is important that some minimum standards be recognized. For example, there are available private sources of company production, labour employed, R&D expenditure,

etc. data, that claim to disaggregate each company's basic data into distinguished lines of business or market activities. One such collection of data is used by Clark and Griliches [2] and is based on the PIMS (Profit Impact of Market Strategy) Project of the Strategic Planning Institute. To quote from Scherer [16, p. 271].

> "Beginning with 1970, a group of typically large corporations began supplying to a private organization elaborately detailed performance and structure data on certain of their individual "businesses", defined as company units selling a distinct set of products or services in competition with a well-defined set of competitors. By 1978, the PIMS data set had grown to cover some 1,000 such businesses operated by more than 200 corporations".

The PIMS data base, however, has certain limitations. There is a degree of self-selection for both companies taking part in the project and their chosen definition of "businesses" for which production and R&D data are made available. This means that intercompany comparisons become difficult. Similarly much of the structural data reflects the companies' individual assessments and perceptions (stated by Clark and Griliches [2]). The particular reporting procedures do not appear to be constrained to

standardized industrial classifications. Moreover, of course, such private sources of information do not have complete or substantive sectoral coverage. When no other data exist, then the use of PIMS-type data might be recommended. There is, nevertheless, no real substitute for a rigorous line of business financial reporting program such as that performed by the FTC during the years 1974-78.12

Notes - D

1 Note that individual establishments can also be heterogenous with respect to commodity output and this fact is reflected in the rectangular array of "make" and "use" matrices underlying Canadian input-output tables and deployed in the productivity growth study of Postner and Wesa [13].

2 The field is evidently a synthesis of cost accounting, microeconomic theory, statistical method and operations research. A leading nontechnical text is Sizer [17]. The field is currently undergoing a computer revolution.

3 Clearly, some minimum size standards must be met for this requirement to be feasible.

4 It is not only access to information that counts; the proper interpretation of company accounting records is also important (accounting numbers are notoriously "soft").

5 Thus we do not, in this paper, draw a distinction between basic R&D and applied R&D; the latter type is mostly assumed. Note that R&D institutes are mainly government supported and, therefore, not part of the business sector.

6 The present writer has no knowledge of R&D accounting systems constructed for Canadian companies, but there are U.S. and U.K. references on the subject.

7 For further discussion of this point see Postner and Wesa [13, Ch. 4].

8 FTC has prepared a cost-benefit analysis of the LOB reporting program.

9 The discussion here is limited to industrial users of R&D; much R&D is also directly consumer-oriented which is not our present concern.

10 See, e.g., the work of Scherer [15] with patent statistics. There are also problems with respect to price deflation and associated market conditions under which new products are sold.

11 Note, also, the importance of embodying time lags in any study relating productivity growth to R&D expenditures. This calls for sufficiently long time series of data observations.

12 Problems relating to cost and respondent-burden are briefly mentioned in the next section; see also Scherer [14] and FTC [3].

E. CONCLUSION

In Canada today, there is much discussion and literature concerning the role of R&D expenditures in stimulating productivity growth, international competitiveness, and even high-profile employment. The most recent series of Federal Canadian Budgets gave prominance to various R&D taxation incentive and credit schemes designed to raise R&D expenditure levels in the business sector. Indeed, the latest industrial R&D data show that R&D as a percentage of GNP has increased significantly and this trend is expected to continue during the 1980's. In view of all this, it seems natural to re-examine the nature of available R&D data, in the light of other available data, for the purpose of measuring the potential benefits of increased R&D expenditures and connected policies. This paper is solely concerned with problems of relating R&D to productivity growth, and even for this limited objective, we find that available R&D information in Canada is currently inadequate. Interesting enough, this latter statement should really be modified, since we do not even have sufficient information to show, without a shadow of doubt, that the R&D-productivity statistical incompatibility problem is of a "serious" nature. Nevertheless, there is a distinct impression that the problem should be taken seriously. How, then, can Canadians and economic investigators become better informed about Canada's R&D effort?

First, we would recommend legislation requiring disclosure of R&D expenditures by all large Canadian corporations, both publically- and privately-held. At this moment to our knowledge, according to an OECD survey in Canada [10, p. 154]:

> "There are no disclosure requirements in this area by virtue of legislation".

Examination of a sample of Annual Reports by large Canadian corporations, reveals a somewhat mixed record of voluntary disclosure.

Second, we think, to paraphrase Shakespeare, that Statistics Canada "protests too much". Confidentiality restrictions that made sense in the 1970's are probably no longer valid. One such set of restrictions was already mentioned in Section C of this paper (related to publication of R&D matrix data disaggregated by industry of origin and commodity product field). Similarly it appears to us that there are a considerable number of 3-digit industries with at least three or four R&D performing companies, where distinct R&D expenditure data are not published, supposedly due to confidentiality restrictions. This statement is made on the basis Statistics Canada [21, Table 2] showing industrial distribution of R&D performers, 1980, in terms of number of companies. Although Canadian R&D is heavily concentrated in terms of expenditure performance, there is no doubt a growing number of R&D performers (although relatively

small) in various industries. This fact should be able to loosen the bounds of historical confidentiality limitations.

Third, is it possible for Canada to begin moving in the direction of a rigorous LOB reporting program for all large corporations? At the moment the situation is, according to the OECD survey in Canada [10, p. 157]:

> "Information on diversified operations is now required by some Corporations Acts. For example, the Canadian Business Corporation Act requires financial statements to disclose a summary of financial information for each class of business, the revenue from which is 10% or more of the Corporation's total revenues."

Our brief examination of Canadian Annual Reports reveals, again, a mixed record of compliance even with respect to these mild (and statistically useless) guidelines. Canada, therefore, has considerable distance to go before a FTC-type reporting system can be instituted. Present line of business or segmented financial reporting in Canada is even weaker than that of the SEC in the U.S. which pre-dated the FTC program. Some caution was noted in Section D to the effect that the institution of a FTC system might be difficult in Canada because of problems related to foreign-ownership. On the other hand, the development of a LOB program is

made easier in Canada due to the existence of a centralized statistical collecting system. On balance any such LOB reporting program must reflect the peculiarities and virtues of the particular Canadian situation.

There is, however, one clear lesson that could be learned from FTC and related experience. We should not attempt to introduce a LOB reporting program in "bits and pieces". For example, the recommended allocation of company R&D expenditures to the company's various lines of business (approximating establishment reporting), is best accomplished in the context of a general LOB financial reporting program. The more general objective is: (1) cost-effective, (2) minimizes respondent-burden, and (3) assures a reasonable degree of response consistency. In any event, the guideline details of a LOB reporting program should depend on the nature of the internal management accounting and control systems that typify the large multi-industry Canadian corporations. Perhaps, then, the time has arrived for Canadian government economists and statisticians to open a dialogue with Canadian corporate accountants.

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